PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 24 January 2001 (24.01.01)	
International application No. PCT/GB00/01748	**Applicant's or agent's file reference** FP2690 WO
International filing date (day/month/year) 12 May 2000 (12.05.00)	**Priority date** (day/month/year) 12 May 1999 (12.05.99)
Applicant SAMUEL, Ifor, David, William et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

11 December 2000 (11.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Pascal Piriou

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

27 SEP 2000

From the INTERNATIONAL BUREAU

PCT

To:

MARKGRAAF PATENTS LIMITED
The Crescent
54 Blossom Street
York YO24 1AP
ROYAUME-UNI

NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

Date of mailing (day/month/year) 19 September 2000 (19.09.00)	
Applicant's or agent's file reference FP2690 WO	**IMPORTANT NOTIFICATION**
International application No. PCT/GB00/01748	International filing date (day/month/year) 12 May 2000 (12.05.00)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 12 May 1999 (12.05.99)
Applicant UNIVERSITY OF DURHAM et al	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).

2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.

3. An **asterisk(*)** appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

4. The **letters "NR"** appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, **the attention of the applicant is directed** to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

Priority date	Priority application No.	Country or regional Office or PCT receiving Office	Date of receipt of priority document
12 May 1999 (12.05.99)	9910901.9	GB	04 Sept 2000 (04.09.00)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

R. Raissi

Telephone No. (41-22) 338.83.38

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ _____

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: FP2690 WO

International application No.	International filing date (*day/month/year*)	(Earliest) Priority date (*day/month/year*)
PCT/GB00/01748	12 MAY 2000 (12.05.00)	12 MAY 1999 (12.05.99)

Title of invention:

LIGHT EMITTING DIODE WITH IMPROVED EFFICIENCY

Box No. II APPLICANT(S)

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*)

UNIVERSITY OF DURHAM
OLD SHIRE HALL
DURHAM
DH1 3HP

Telephone No.:

Facsimile No.:

Teleprinter No.:

State (*that is, country*) of nationality:	State (*that is, country*) of residence:
GB	GB

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*)

UNIVERSITY OF EXETER
NORTHCOTE HOUSE
THE QUEEN'S DRIVE
EXETER
EX4 4QJ

State (*that is, country*) of nationality:	State (*that is, country*) of residence:
GB	GB

Name and address: (*Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.*)

SAMUEL, Ifor, David, William
UNIVERSITY OF DURHAM
DEPARTMENT OF PHYSICS
SOUTH ROAD
DURHAM
DH1 3LE

State (*that is, country*) of nationality:	State (*that is, country*) of residence:
GB	GB

[x] Further applicants are indicated on a continuation sheet.

Sheet No. 2

International application No.
PCT/GB00/01748

Continuation of Box No. II **APPLICANT(S)**

If none of the following sub-boxes is used, this sheet should not be included in the demand.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

LUPTON, John, Mark
UNIVERSITY OF DURHAM
DEPARTMENT OF PHYSICS
SOUTH ROAD
DURHAM
DH1 3LE

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
GB	GB

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MATTERSON, Benjamin, James
UNIVERSITY OF DURHAM
DEPARTMENT OF PHYSICS
SOUTH ROAD
DURHAM
DH1 3LE

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
GB	GB

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

BARNES, William, Leslie
SCHOOL OF PHYSICS
UNIVERSITY OF EXETER
PHYSICS BUILDING
STOCKER ROAD
EXETER
DEVON
EX4 4QL

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
GB	GB

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

SALT, Martin, Guy
SCHOOL OF PHYSICS
UNIVERSITY OF EXETER
PHYSICS BUILDING
STOCKER ROAD
EXETER
EX4 4QL

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
GB	GB

☐ Further applicants are indicated on another continuation sheet.

International application No.
PCT/GB00/01748

Box No. III AGENT OR COMMON REPRESENTATIVE: OR ADDRESS FOR CORRESPONDENCE

The following person is [X] agent [ ] common representative

and [X] has been appointed earlier and represents the applicant(s) also for international preliminary examination.

[ ] is hereby appointed and any earlier appointment of (an) agent(s) common representative is hereby revoked.

[ ] is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s) common representative appointed earlier.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MARKGRAAF PATENTS LIMITED
THE CRESCENT
54 BLOSSOM STREET
YORK
YO24 1AP

Telephone No.: 01904 610586

Facsimile No.: 01904 610909

Teleprinter No.:

[ ] **Address for correspondence:** Mark this check-box where no agent or common representative is has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination to start on the basis of:

[ ] the international application as originally filed

the description: [X] as originally filed
[ ] as amended under Article 34

the claims: [ ] as originally filed
[X] as amended under Article 19 (together with any accompanying statement)
[ ] as amended under Article 34

the drawings: [X] as originally filed
[ ] as amended under Article 34

2. [ ] The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. [ ] The applicant wishes the start of the international preliminary examination **to be postponed** until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: ENGLISH

[X] which is the language in which the international application was filed.
[ ] which is the language of a translation furnished for the purposes of international search.
[ ] which is the language of publication of the international application.
[ ] which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No. V ELECTION OF STATES

The applicant hereby **elects all eligible States** *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes **not to elect:**

International application No.
PCT/GB00/01748

Box No. VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:		For International Preliminary Examining Authority use only: received	not received
1. translation of international application	sheets	☐	☐
2. amendments under Article 34	sheets	☐	☐
3. copy (or, where required, translation) of amendments under Article 19	sheets	☐	☐
4. copy (or, where required, translation) of statement under Article 19	sheets	☐	☐
5. letter	sheets	☐	☐
6. other *(specify)*	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ nucleotide and or amino acid sequence listing in computer readable form
6. ☐ other *(specify)*:

Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs if such capacity is not obvious from reading the demand.

MARKGRAAF PATENTS LIMITED

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

CHAPTER II

PCT

FEE CALCULATION SHEET

Annex to the Demand for international preliminary examination

International application No	PCT/GB00/01748
Applicant's or agent's file reference	FP2690 WO

For International Preliminary Examining Authority use only

Date stamp of the IPEA

Applicant

UNIVERSITY OF DURHAM & EXETER

Calculation of prescribed fees

1. Preliminary examination fee	981.00	P
2. Handling fee *(Applicants from certain States are entitled to a reduction of 75% of the handling fee. Where the applicant is (or all applicants are) so entitled, the amount to be entered at H is 25% of the handling fee.)*	94.00	H
3. Total of prescribed fees Add the amounts entered at P and H and enter total in the TOTAL box	1075.00 GBP	TOTAL

Mode of Payment

- [ ] authorization to charge deposit account with the IPEA (see below)
- [X] cheque
- [ ] postal money order
- [ ] bank draft
- [ ] cash
- [ ] revenue stamps
- [ ] coupons
- [ ] other *(specify)*

Deposit Account Authorization *(this mode of payment may not be available at all IPEAs)*

The IPEA ____ [ ] is hereby authorized to charge the total fees indicated above to my deposit account.

[X] *(this check-box may be marked only if the conditions for deposit accounts of the IPEA so permit)* is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.

D10007	11/12/2000	Markgraaf Patents Ltd
Deposit Account Number	Date *(day/month/year)*	Signature Markgraaf Patents Limited

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No

International Filing Date

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* FP2690 WO

Box No. I TITLE OF INVENTION

LIGHT EMITTING DIODE WITH IMPROVED EFFICIENCY

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

UNIVERSITY OF DURHAM
OLD SHIRE HALL
DURHAM
DH1 3HP
GREAT BRITAIN

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

UNIVERSITY OF EXETER
NORTHCOTE HOUSE
THE QUEEN'S DRIVE
EXETER
EX4 4QJ
GREAT BRITAIN

This person is:

☒ applicant only

☐ applicant and inventor

☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

MARKGRAAF PATENTS LIMITED
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+44 (0) 1904 610909

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Continuation of Box No. III **FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)**

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*
SAMUEL, Ifor David William
DEPARTMENT OF PHYSICS
UNIVERSITY OF DURHAM
SOUTH ROAD
DURHAM
DH1 3LE
GREAT BRITAIN

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

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LUPTON, John Mark
DEPARTMENT OF PHYSICS
UNIVERSITY OF DURHAM
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DH1 3LE
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MATTERSON, Benjamin James
DEPARTMENT OF PHYSICS
UNIVERSITY OF DURHAM
SOUTH ROAD
DURHAM
DH1 3LE
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BARNES, William Leslie
SCHOOL OF PHYSICS
UNIVERSITY OF EXETER
PHYSICS BUILDING, STOCKER ROAD
EXETER
DEVON EX4 4QL
GREAT BRITAIN

This person is:
☐ applicant only
☒ applicant and inventor
☐ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on another continuation sheet.

Continuation of Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet should not be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

SALT, Martin Guy
SCHOOL OF PHYSICS
UNIVERSITY OF EXETER
PHYSICS BUILDING, STOCKER ROAD
EXETER
DEVON EX4 4QL
GREAT BRITAIN

This person is:
- [ ] applicant only
- [X] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [X] the United States of America only [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:
- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

[ ] Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No. V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

- [x] AP **ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SL** Sierra Leone, **SZ** Swaziland, **TZ** United Republic of Tanzania, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- [x] EA **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- [x] EP **European Patent:** **AT** Austria, **BE** Belgium, **CH** and **LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- [x] OA **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Côte d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

- [x] AE United Arab Emirates
- [x] AL Albania
- [x] AM Armenia
- [x] AT Austria
- [x] AU Australia
- [x] AZ Azerbaijan
- [x] BA Bosnia and Herzegovina
- [x] BB Barbados
- [x] BG Bulgaria
- [x] BR Brazil
- [x] BY Belarus
- [x] CA Canada
- [x] CH and LI Switzerland and Liechtenstein
- [x] CN China
- [x] CR Costa Rica
- [x] CU Cuba
- [x] CZ Czech Republic
- [x] DE Germany
- [x] DK Denmark
- [x] DM Dominica
- [x] EE Estonia
- [x] ES Spain
- [x] FI Finland
- [x] GB United Kingdom
- [x] GD Grenada
- [x] GE Georgia
- [x] GH Ghana
- [x] GM Gambia
- [x] HR Croatia
- [x] HU Hungary
- [x] ID Indonesia
- [x] IL Israel
- [x] IN India
- [x] IS Iceland
- [x] JP Japan
- [x] KE Kenya
- [x] KG Kyrgyzstan
- [x] KP Democratic People's Republic of Korea
- [x] KR Republic of Korea
- [x] KZ Kazakhstan
- [x] LC Saint Lucia
- [x] LK Sri Lanka
- [x] LR Liberia
- [x] LS Lesotho
- [x] LT Lithuania
- [x] LU Luxembourg
- [x] LV Latvia
- [x] MA Morocco
- [x] MD Republic of Moldova
- [x] MG Madagascar
- [x] MK The former Yugoslav Republic of Macedonia
- [x] MN Mongolia
- [x] MW Malawi
- [x] MX Mexico
- [x] NO Norway
- [x] NZ New Zealand
- [x] PL Poland
- [x] PT Portugal
- [x] RO Romania
- [x] RU Russian Federation
- [x] SD Sudan
- [x] SE Sweden
- [x] SG Singapore
- [x] SI Slovenia
- [x] SK Slovakia
- [x] SL Sierra Leone
- [x] TJ Tajikistan
- [x] TM Turkmenistan
- [x] TR Turkey
- [x] TT Trinidad and Tobago
- [x] TZ United Republic of Tanzania
- [x] UA Ukraine
- [x] UG Uganda
- [x] US United States of America
- [x] UZ Uzbekistan
- [x] VN Viet Nam
- [x] YU Yugoslavia
- [x] ZA South Africa
- [x] ZW Zimbabwe

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

- [x] DZ Algeria
- [x] AG Antigua & Barbuda

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation (including fees) must reach the receiving Office within the 15-month time limit.)*

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day month year)	Number of earlier application	Where earlier application is: national application: country	regional application: * regional Office	international application: receiving Office
item (1) 12-05-1999	9910901.9	GB		
item (2)				
item (3)				

☐ The receiving Office is requested to prepare and transmit to the international Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): _____

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used)*

ISA/

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority).*

Date *(day month year)* Number Country *(or regional Office)*

Box No. VIII CHECK LIST; LANGUAGE OF FILING

This international application contains the following **number of sheets**:

request	5
description (excluding sequence listing part)	20
claims	5
abstract	1
drawings	7
sequence listing part of description	
Total number of sheets	38

This international application is **accompanied by** the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and or amino acid sequence listing in computer readable form
9. ☐ other *(specify)*

Figure of the drawings which should accompany the abstract:

Language of filing of the international application: ENGLISH

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Markgraaf Patents Ltd

MARKGRAAF PATENTS LIMITED - 12.05.2000

For receiving Office use only

1. Date of actual receipt of the purported international application:
2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:
4. Date of timely receipt of the required corrections under PCT Article 11(2):
5. International Searching Authority (if two or more are competent): ISA/
6. ☐ Transmittal of search copy delayed until search fee is paid.

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
FP2690 WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 01748	12/05/2000	12/05/1999
Applicant		
UNIVERSITY OF DURHAM et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 2

   [ ] as suggested by the applicant.

   [X] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01748

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20 H01L33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MATTERSON B J ET AL: "Effect of lateral microstructure on conjugated polymer luminescence" INTERNATIONAL CONFERENCE ON SCIENCE AND TECHNOLOGY OF SYNTHETIC METALS, MONTPELLIER, FRANCE, 12-18 JULY 1998, vol. 101, no. 1-3, pages 250-251, XP000931170 Synthetic Metals, May 1999, Elsevier, Switzerland ISSN: 0379-6779 the whole document --- -/--	1-8, 11-19, 22,23, 25-34

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2000	13/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

1

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/GB 00/01748

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 25313 A (BARNES WILLIAM LESLIE ;BRITISH TECH GROUP (GB); KITSON STEPHEN CHR) 11 June 1998 (1998-06-11) abstract	1-4,6, 10-16, 19,20, 27,31, 33,34
A	SHANHUI FAN ET AL: "High extraction efficiency of spontaneous emission from slabs of photonic crystals" PHYSICAL REVIEW LETTERS, 28 APRIL 1997, APS, USA, vol. 78, no. 17, pages 3294-3297, XP000931171 ISSN: 0031-9007 the whole document	1-4,6, 12,20, 21,24
A	WINDISCH R ET AL: "Light-emitting diodes with 31% external quantum efficiency by outcoupling of lateral waveguide modes" APPLIED PHYSICS LETTERS, 19 APRIL 1999, AIP, USA, vol. 74, no. 16, pages 2256-2258, XP002145910 ISSN: 0003-6951 cited in the application	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01748

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9825313 A	11-06-1998	EP 0946994 A	06-10-1999

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
FP2690 WO		

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01748	12/05/2000	12/05/1999

International Patent Classification (IPC) or national classification and IPC
H01L51/20

Applicant
UNIVERSITY OF DURHAM et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
11/12/2000	07.08.2001

Name and mailing address of the international preliminary examining authority:
European Patent Office
D-80298 Munich
Tel. +49 89 2399 - 0 Tx: 523656 epmu d
Fax: +49 89 2399 - 4465

Authorized officer
Krause, J
Telephone No. +49 89 2399 2829

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01748

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-20	as originally filed			

Claims, No.:

1-32	as received on	07/05/2001	with letter of	04/05/2001

Drawings, sheets:

1/7-7/7	as received on	14/07/2000	with letter of	03/07/2000

2 With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	7, 9, 15, 16, 20, 21, 23, 26, 27, 29
	No:	Claims	1 - 6, 8, 10 - 14, 17 - 19, 22, 24, 25, 28, 30 - 32
Inventive step (IS)	Yes:	Claims	7
	No:	Claims	1 - 6, 8 - 32
Industrial applicability (IA)	Yes:	Claims	1 - 32
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Concerning Section V:

I. Claim 1:

1. The document WO-A-98/25313 (= D1) describes a light emitting diode (cf. page 8, lines 3 to 7, and Fig. 5), which comprises one or more intermediate semiconductor layers (55) and optionally one or more further layers, wherein the LED comprises at least one substantially periodic microstructured feature (53) adapted to manipulate emission and/or propagation of light by coupling non-radiative waveguide-modes to far-field radiation. Since the light emitting device in document D1 is fabricated from a sequence of layers on a substrate (51), it is implicitly clear that the LED must have two electrodes, one adapted for electron injection and one adapted for hole injection, sandwiching the layer structure. As a consequence, all the features of claim 1 are anticipated by document D1, and therefore claim 1 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. The document WO-A-98/25314 (= D2), has not been cited in the International Search Report. It describes (cf. page 7, line 21, to page 14, line 32, and Figs. 5 and 6) a light emitting diode having a microstructured feature adapted to manipulate emission or propagation of light as well. Also in document D2 electrodes are not explicitly described, but they belong to a light emitting diode and are therefore implicitly disclosed.

3. The arguments of the applicants put forward in their letter of 4 May 2001 are not convincing, because structural differences between the microstructured features of the device according to claim 1 and of the devices according to documents D1 or D2 have to be specified in the claim. At present, the microstructured feature of claim 1 should be the same as in D1 or D2.

II. Claims 2 to 22:

1. The additional features of dependent claims 2, 5, 6, and 8 are known from document D2. Therefore claims 2, 5, 6, and 8 do not appear to meet the requirements of Article

33(2) and (3) PCT.

2. As is described in document D2, only certain modes of the radiation field can oscillate in the light emitting diode. These modes differ from each other eg in the polarisation. Therefore the additional features of claim 3 are also known from document D2, and claim 3 is not considered to meet the requirements of Article 33(2) and (3) PCT.

3. The additional features of claims 4, 10, and 22 are known from either one of documents D1 and D2, and therefore claims 4, 10, and 22 are not considered to meet the requirements of Article 33(2) and (3) PCT.

4. The additional feature of claim 7 is not known nor rendered obvious from the available prior art. Claim 7 is therefore considered to meet the requirements of Article 33(2) and (3) PCT.

5. A person skilled in the art of semiconductor optical devices knows that the size of any feature designed to influence the emitted light depends on the wavelength of said light. He would thus obtain sizes as specified in claims 9, 15, and 16 by routine optimisation of parameters, taking into account his specific needs. Claims 9, 15, and 16 are thus not considered to meet the requirement of Article 33(3) PCT.

6. The additional features of claims 11 to 14 and 17 are known from document D1, and therefore claims 11 to 14 and 17 are not considered to meet the requirements of Article 33(2) and (3) PCT.

7. The additional features of claims 18 and 19 are known from document D2. Thus claims 18 and 19 do not appear to meet the requirements of Article 33(2) and (3) PCT.

8. The use of semiconducting organic materials in light emitting devices is generally known and would therefore also be contemplated in a device according to document D1 or document D2. Claims 20 and 21 are therefore not considered to meet the requirement of Article 33(3) PCT.

III. Claims 23 and 24:

1. As has been pointed out in the preceding paragraph II.8, semiconducting organic layers are generally known in the art. The provision of a lateral microstructure is described in document D2, and it is also evident to use such an organic layer in a light emitting diode. Thus the person skilled in the art would obtain all the features of claim 23 without employment of inventive skill, and therefore claim 23 does not appear to meet the requirement of Article 33(3) PCT.

2. The use of an LED in any light emitting display is self-evident for a person skilled in the art and has often been described. The person skilled in the art knows the subject-matter of claim 24 from his general knowledge, and therefore claim 24 is not considered to meet the requirements of Article 33(2) and (3) PCT.

IV. Claims 25 to 30:

1. The documents D1 and D2 describe also a method for the production of a light emitting diode, wherein a laminar structure is fabricated comprising one or more intermediate semiconductor layers and one ore more further layers, and further comprising the step of adapting the LED such that there is at least one substantially periodic microstructured feature adapted to manipulate emission or propagation of light by coupling non-radiative waveguide-modes to far-field radiation. The fabrication of two opposing electrodes is not mentioned but implicitly clear from document D1 or document D2. Thus all the features of claim 25 are known from either one of documents D1 and D2, and claim 25 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. The additional feature of dependent claim 26 is obvious from the fact that semiconducting organic layers are generally known and from documents D1 or D2. Therefore claim 26 is not considered to meet the requirement of Article 33(3) PCT.

3. The additional features of claim 27 are generally known to a person skilled in the art of organic semiconducting materials. Claim 27 is therefore also not considered to meet the requirement of Article 33(3) PCT.

4. The additional features of claims 28 and 30 are known from document D1 (cf. page 10, line 10, to page 12, line 13). Thus claims 28 and 30 are not considered to meet the requirements of Article 33(2) and (3) PCT.

5. The use of a laser beam as a light source is readily at the disposal of a skilled process engineer. Therefore claim 29 is not considered to meet the requirement of Article 33(3) PCT.

V. Claims 31 and 32:

1. A light emitting device as in claim 31 is known from document D1 or document D2. Therefore claim 31 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. A method as in claim 32 is known from document D1 or D2. Thus claim 32 is also not considered to meet the requirements of Article 33(2) and (3) PCT.

Concerning Section VII:

1. Claims 31 and 32 contain references to the description and the drawings. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here. Claims 31 and 32 should therefore be deleted.

2. Independent claims 1 and 25 are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

3. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art

disclosed in the documents D1 and D2 is not mentioned in the description, nor are these documents identified therein.

Concerning Section VIII:

1. Claims 2, 3, 5, 6, and 8 describe the features of the device in terms of a result to be achieved. Such a wording is not clear in the sense of Article 6 PCT, since the person skilled in the art reading the claims would need inventive thought to put the invention into practice.

2. The use of the word "substantially" in claims 1, 2, 4, and 25 obscures the scope of protection sought by these claims (Article 6 PCT).

3. Claim 23 refers to all preceding claims, but the semiconducting organic or organometallic layer is only defined in claims 20 and 21 (Article 6 PCT).

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H01L 51/20, 33/00 — A1

(11) International Publication Number: WO 00/70691

(43) International Publication Date: 23 November 2000 (23.11.00)

(21) International Application Number: PCT/GB00/01748

(22) International Filing Date: 12 May 2000 (12.05.00)

(30) Priority Data:
9910901.9 12 May 1999 (12.05.99) GB

(71) Applicants *(for all designated States except US)*: UNIVERSITY OF DURHAM [GB/GB]; Old Shire Hall, Durham DH1 3HP (GB). UNIVERSITY OF EXETER [GB/GB]; Northcote House, The Queen's Drive, Exeter EX4 4QJ (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: SAMUEL, Ifor, David, William [GB/GB]; University of Durham, Department of Physics, South Road, Durham DH1 3LE (GB). LUPTON, John, Mark [GB/GB]; University of Durham, Department of Physics, South Road, Durham DH1 3LE (GB). MATTERSON, Benjamin, James [GB/GB]; University of Durham, Department of Physics, South Road, Durham DH1 3LE (GB). BARNES, William, Leslie [GB/GB]; School of Physics, University of Exeter, Physics Building, Stocker Road, Exeter, Devon EX4 4QL (GB). SALT, Martin, Guy [GB/GB]; School of Physics, University of Exeter, Physics Building, Stocker Road, Exeter EX4 4QL (GB).

(74) Agent: MARKGRAAF PATENTS LIMITED; The Crescent, 54 Blossom Street, York YO24 1AP (GB).

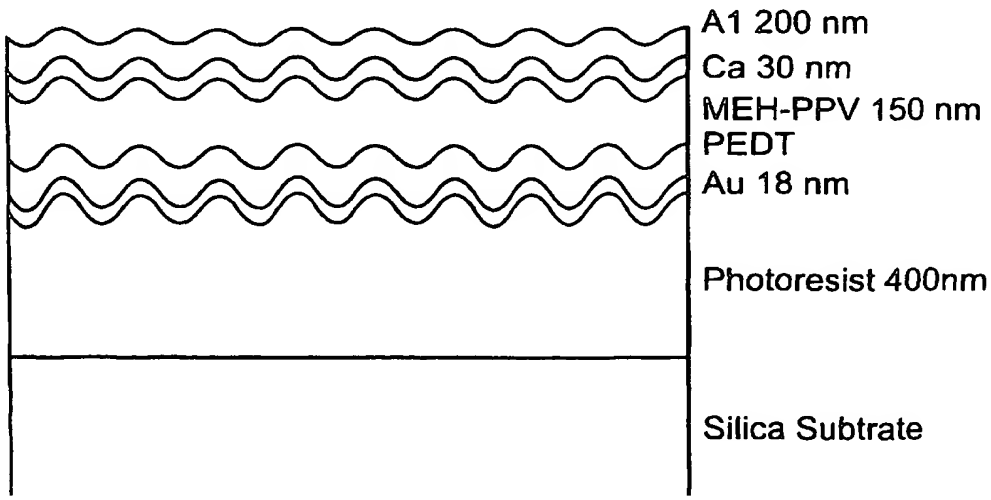
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: LIGHT EMITTING DIODE WITH IMPROVED EFFICIENCY



(57) Abstract

An LED, and in particular an LED employing emissive semi–conductors such as conjugated polymeric materials, consists of a pair of electrodes, one or more intermediate semi–conductor layers arranged therebetween and optionally one or more futher layers, and incorporates a microstructured feature adapted to manipulate spontaneous emission or propagation of light. The invention also consists of a method for the production of such an LED and the use of such a LED as an light emitting display.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
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EE	Estonia	**LR**	Liberia	**SG**	Singapore		

LIGHT EMITTING DIODE WITH IMPROVED EFFICIENCY

The present invention relates to novel light emitting diodes (hereinafter LEDs), components and uses thereof, to a process for the production thereof and a method for light emission. More particularly the present invention relates to novel organic LEDs adapted for improved efficiency light emission, and provides a way of controlling the polarisation and spectrum of the emitted light. It relates to uses of such devices in light-emitting displays including LCDs (Liquid Crystal Displays) and the like, to a process for the production thereof and a method for light emission.

The invention has applications in light-emitting displays, such as for calculators, clocks, mobile phones, computers, information display and elsewhere. It may be used in a display in which a pattern of LEDs is employed or alternatively as a backlight for an LCD. Many further applications will be apparent to the reader familiar with LED technology and include use as an electroluminescent screen, as a light source, lit control button and the like.

Light emission from materials can occur as a result of optical or electrical stimuli. The former process is known as photoluminescence and the latter process is known as electroluminescence. Both processes are well known in a wide range of semiconductors. Electroluminescence occurs in LEDs.

LEDs are semiconducting electronic devices in which the injection of negative and positive charges (known in the art as electrons and holes respectively) leads to the emission of light from the device. The light-emitting material may be organic or inorganic.

An LED may consist of several layers or regions adapted for charge injection,

charge transport, and light-emission. Each layer or region may be an organic or inorganic material.

Semiconducting inorganic LEDs are known, employing inorganic semiconducting materials for all the above charge transporting and light-emitting purposes. Light-emission occurs at a junction between p-type and n-type doped semiconducting regions. Inorganic semiconductors are generally crystalline materials with complicated (but well-established) manufacturing procedures. Gallium compounds and alloys are commonly used.

An organic light emitting diode (LED) consists of one or more organic layers adapted for charge transport and/or light-emission sandwiched between two charge injecting electrodes, of which one is usually transparent.

Both polymers and small conjugated organic molecules are suitable as constituent layers for organic LEDs. Examples of suitable polymers include poly(*p*-phenylenevinylene) (PPV) and derivatives such as poly[2-methoxy, 5-2'-ethyl-hexyloxy)-1,4-phenylene vinylene] (MEH-PPV), polyfluorene and polypyridine. Examples of suitable small organic molecules include metal chelates such as aluminium *tris*quinolate (Alq3). The work functions of the electrodes are adapted for the injection of charge into the organic layers. Materials with relatively high work function such as indium tin oxide (ITO) or gold are suitable for hole injection, and ITO is particularly convenient because of its transparency. Materials with low work function are commonly selected for electron injection, such as aluminium, calcium, lithium, magnesium, alloys and admixtures thereof.

A simple organic LED can be made by spin-coating a polymer such as MEH-PPV onto an ITO-coated substrate followed by evaporation of a top metal contact. It is also known that organic layers can be deposited successfully by

printing.

The operation of an LED involves many steps: charge injection, charge transport, recombination of opposite charges, light emission, and light escape from the device. The efficiency of an LED (which can be defined as the number of photons emitted divided by the number of charges passing through the device) depends on the fraction of injected charges which recombine with an opposite charge, the fraction of resulting recombination processes which generate light, and the fraction of the light generated in the device which escapes from the device.

In general, the light emitted from LEDs is unpolarised. However, for some applications, notably backlighting of LCDs, a source of polarised light is desirable.

A serious problem with LEDs is the trapping of light emitted by the emissive layer in waveguide modes within the substrate. This may reduce the overall external device efficiency dramatically. For example in the case of organic LEDs it has been proposed that only a fraction $1/2n^2$ of the light generated inside the LED escapes from it, where n is the refractive index of the organic layer (Angular Dependence of the Emission from Conjugated Polymer Light-emitting Diode: Implications for Efficiency Calculations, N.C. Greenham, Adv. Mat. 1994, 6, No 6).

Taking a refractive index of 2 (typical of a conjugated polymer such as PPV) would imply that seven eighths of the light generated inside the device is trapped there, and only one eighth escapes. In inorganic semiconductors the same considerations apply and refractive indices are higher (a typical value is 3.5). It has been estimated that only 3% of the light generated in a planar LED will escape (see for example D. Wood, Optoelectronic Semiconductor Devices,

Prentice Hall, Hemel Hempstead, 1994, page 86)

The present invention provides a novel way of improving LED performance by increasing and controlling the light coupling out of the device.

It is important to appreciate that the invention concerns the adaptation of LEDs for improved efficiency light emission, and for enabling control of the polarisation and spectrum of the emitted light. LED devices operate by spontaneous emission of radiation, in contrast to lasers which operate by stimulated emission of radiation with spatial and temporal coherence of the emitted light, a threshold current for light emission, and (usually) single-wavelength operation. LEDs are generally much simpler, cheaper and more robust than lasers, and any adaptation of LEDs for improved efficiency should therefore be similarly simple, cheap and robust.

Emissive species embedded in the emissive layer of an LED structure emit their energy into the available modes of the structure, these modes include: radiative modes, the ones that produce useful radiation; trapped guided modes, including waveguide modes and surface plasmon polariton modes associated with the metal contacts. In addition, emissive species (emitters) may lose their energy via non-radiative decay, for example resulting in the generation of phonons.

The different radiative modes are characterised by their frequency and in-plane wavevector. Modes having in-plane wavevectors less than free space photons of the same frequency may escape the LED structure and are responsible for the useful radiation from planar LEDs. Modes having a higher wavevector are not able to radiate into free space, these radiative modes are thus trapped (waveguided) in the layers that comprise the LED structure. These latter trapped modes may carry the majority of the energy.

Various attempts have been made to raise external device efficiency by macro-roughening the exit surface by which light leaves the device (for example US 3 739 217 and US 4 080 245). Random roughening of surfaces has been shown to increase light output (R. Windisch et al. Applied Physics Letters, 74 (1999) 2256-2258).

Other methods of raising efficiency are the provision of internal channels and/or microcavities (US 4, 856 014, Control of photoluminescence emission from a conjugated polymer using an optimised microcavity structure, D.G. Lidzey et al, Chemical Physics Letter 263 (1996) 655-660).

However, there still exists a need to improve the efficiency of light emission of an LED. Furthermore, none of the above approaches gives any control over the polarisation of the emitted light. We have now surprisingly found that it is possible to provide a semiconducting LED meeting these requirements in admirable manner.

We have also surprisingly found that the present invention gives some control of the spectrum of emitted light, and improves the electrical characteristics of the LED such that light emission starts at a lower voltage.

In its broadest aspect there is provided according to the present invention a light emitting diode (LED), comprising an electrode adapted for electron injection, a second opposing electrode adapted for hole injection, one or more intermediate semi-conductor layers arranged therebetween and optionally one or more further layers wherein the device comprises at least one microstructured feature adapted to manipulate spontaneous emission or propagation of light.

The microstructured feature is suitably comprised as part of an intermediate layer, an electrode, and/or a further layer such as a surface layer which may for example be an external "cladding" layer or the like. It will be apparent that the manipulation may therefore be effective at any stage in the generation, propagation or emission of light in order to modify the properties of light emitted such as intensity, polarisation or spectrum.

The microstructured feature as hereinbefore defined may be of any form adapted to control emission and preferably comprises a substantially periodic microstructure which is effective in controlling intensity, polarisation or spectrum of the emitted light.

Without being limited to this theory, we have found that the invention provides in novel and surprising manner a mechanism by which the above requirements are met which may be in the form of Bragg scattering from substantially periodic microstructure.

The main advantages of periodic microstructure in an LED are increased efficiency, increased brightness, increased total light output, improved polarisation purity of the emitted radiation and control of the spectral variation of the emitted radiation with emission angle, as explained hereinafter.

Guided modes produced by emission from the emitters in the structure are Bragg scattered by the microstructure to produce useful radiation from the device. In this way light that would otherwise have been trapped in the emissive layer is, at least in part, recovered thus improving efficiency.

Through Bragg scattering the microstructure changes the in-plane wavevector of the guided modes. The wavevector of trapped waveguide modes may be decreased, allowing these modes to radiate. However, radiative modes may have their wavevector increased, thus trapping them in the structure. The net

result is a surprising improvement in efficiency because, as we have demonstrated, the microstructure enables more energy to be scattered out of the device than it traps.

The emission radiated from planar LED devices is in general un-polarised. With the addition of microstructure, much of the emitted radiation results from the extraction of waveguide modes by the Bragg scattering process. The polarised nature of the waveguided modes and the vectoral nature of the Bragg scattering process by which they are coupled to useful radiation means that periodic microstructure can be used to control the polarisation state of the emitted radiation.

As a further result of the Bragg scattering process, the frequency of the radiation emitted in a given direction is dictated by the profile of the microstructure. Consequently, the spectral variation of the radiated output with emission angle may be controlled. The microstructured layers can consist of many regions of different periodicity to couple out light of different colours.

In addition to the uses of periodic microstructure mentioned hereinbefore, periodic microstructure can be used to modify the nature of the waveguided modes supported by the LED structure. By controlling the microstructure incorporated into the LED structure, in particular the periodicity thereof, the microstructure can be used to control the nature of the guided modes that the LED structure may support. This in turn allows greater control over the radiation emitted by the LED as follows.

Periodic microstructure, in addition to providing Bragg scattering to allow the extraction of waveguide modes, also results in the an alteration of the photonic band structure supported by layered structures [M. G. Salt and W. L. Barnes, "Photonic Band Gaps in Guided Modes of Textured Metallic Microcavities"

Accepted for publication by Optics Communications. (accepted April 1999).]

In particular, Bragg scattering of waveguide modes may be used to produce band gaps in the propagation of these modes. The frequency of the centre of this gap and its width (in frequency) are dictated by the profile of the microstructured interfaces together with the dielectric properties of the materials from which the layers that comprise the LED are made.

Additionally, because of the vector nature of the Bragg scattering process, the central frequency of the gap depends on the in-plane propagation direction of the waveguide mode. Importantly, if the frequency of the emission from the emitters embedded in the LED structure lies in the photonic band gap for a particular in-plane direction, the emitters are unable to generate waveguide modes propagating in that direction. Conversely, if the frequency of the emission from the emitters embedded in the LED structure lies at one of the edges of the photonic band gap for a particular in-plane direction, the generation of waveguide modes propagating in that direction is enhanced.

Suitable tailoring of the photonic band-structure of the LED through appropriate periodic microstructure thus allows for the preferential excitation of a desired waveguide mode. This may allow for an additional increase in efficiency over and above that due to extracting guided modes by Bragg scattering. The higher mode density associated with a mode at the edge of a photonic band gap further enhances the overall efficiency of the device by ensuring that emission by the emitters into waveguide modes preferentially produces waveguide modes that propagate in an in-plane direction that the microstructure is able to couple to useful radiation.

An additional benefit of this increased efficiency is that there is an associated

increase in the decay rate of emission from the emitters, owing to the flattened photonic bands. This may prove advantageous when high modulation rates are required, or emitters suffering from significant non-radiative decay are to be used. Further, by preferentially enhancing the emission from the emitters into waveguide modes propagating in selected in-plane directions, additional improvements in the polarisation purity of the emitted radiation can be achieved, over and above that due to extracting guided modes by Bragg scattering.

Reference herein to a layer is to a substantially uniform discrete layer of a material, the properties of which are suited to the function of the layer. Accordingly, it will be apparent that individual layers are distinguished by nature of configuration or component material, which may comprise one or a plurality of chemical entities present as a physical or chemical mixture. The electrodes may form an entire layer of the LED or may be present as discrete areas within a layer or on the surface of the LED.

Preferably, at least one semiconducting layer or a component thereof, is capable of light emission by luminescence. Preferably, the emissive layer(s) or component thereof are substantially coincident with the junction of coincidence of charge carriers. More preferably the or each semiconducting layer is substantially emissive.

Reference herein to electrons and holes is to negative and positive charge carriers respectively, as known in the art, also known as negative and positive polarons.

Reference herein to microstructure is to a structure having features and/or properties characterised by a small scale, such as microscopic. Features may be in the form of physical structuring, such as corrugation. Properties may be in

the form of micro variations in refractive index by composition variation, ion implantation or other methods and the like. Preferably, the microstructure is of microscopic scale.

Reference herein to substantially periodic microstructure is to microstructure at least one section of which has a substantially regular period. The periodicity of the microstructure may be uniform throughout or the microstructure may have sections with differing periodicity. Both of these may form a pattern or array.

The microstructure may have any suitable period or range of periods of features and/or properties to give the effect of improved efficiency. Preferably, the period is of microscopic scale. More preferably, the period is in the order of 50 – 2000 nanometers, more preferably between 100 and 600 nm. In one preferred embodiment the period is between 350 and 450 nm and ideally 400nm.

Preferably the microstructure is solid such that any or all microstructured layers are continuous, that is, do not comprise any form of perforation containing no material or a material of appreciably lower optical density within their structure.

The microstructure is preferably generally lateral, that is, extends in a substantially parallel plane to the semiconducting layer and/or further layers and/or LED structure. The microstructure may be present in any lateral extent of the defined layers or electrodes. For example, it may extend over substantially all of the microstructured layer(s) or electrode(s), a substantial part thereof or a small part thereof. Preferably, the microstructure extends over a substantial part thereof, more preferably over substantially all thereof.

The microstructured layer(s) and/or electrode(s) may extend in any lateral extent of the LED structure. Preferably, they extend over substantially all of the

LED structure.

A device as hereinbefore defined may comprise any further layers of the LED, such as supporting, sealing, protective or conductive layers and the like. The microstructure may be present in any or all of these further layers. Its presence may be related to the method of fabrication or selected by other criteria.

The microstructured layer(s) and or electrodes(s) may comprise a microstructure on one or both surfaces thereof or the microstructure may extend throughout the device. Preferably, the microstructure provides the entirety of at least one of the microstructured layers and/or electrodes. This has advantages of ease of manufacture in view of the low thickness of the LED layers (of the order of 20-100 nm), which complicates physical manipulation within the layer or of one surface of the layer only.

Preferably, the microstructure acts as a diffraction grating. This can be created by properties or structures as hereinbefore defined.

In one preferred embodiment the microstructure comprises features in the form of physical structuring, preferably corrugation. Preferably the corrugation is in the form of one or more non-planar surfaces or layers and comprises an array of opposed projecting portions. The projections may be of any desired shape, such as sinusoidal, rectangular, jagged, pointed or the like.

The array may give, for example, a sinusoidal, square or other wave form of the layer or surface such that each projecting portion extends laterally across the layer (sometimes known as one-dimensional corrugation). Alternatively, the array may be cross-corrugated to give a dimpled form of the surface such that a projecting portion is surrounded by opposed projecting portions (sometimes known as two- or multi-directional corrugation).

The corrugation may be of any suitable depth to improve efficiency. Preferably, the depth between peaks and troughs is of the order 5 to hundreds of nanometers. More preferably it is between 10 and 200 nm, even more preferably between 20 and 120 nm.

The corrugation is preferably in the entirety of the layer. The thickness of a semiconducting layer in an organic LED is of the order of 100 nm. Surprisingly we have found that at the preferred depths of corrugation, the electrical and emission properties of the semiconducting layer are not detrimentally affected, despite the high ratio of corrugation depth to layer depth, which is close to 1:1.

Where the microstructure comprises modified refractive index, the portions of the layer with modified refractive index are present within the layer and are in the form of lines or areas of modified refractive index laterally across the layer. The refractive index profile in the plane of the layer modified by such microstructure may take the form of, for example, a sinusoidal, square or other waveform of the refractive index.

For organic LEDs, an electrode as hereinbefore defined adapted for electron injection is suitably comprised of any suitable electron injecting material for example as known in the art, preferably comprises any suitable metal, alloy or semi-conductor such as aluminium, lithium-aluminium, calcium or magnesium-silver, magnesium, magnesium-aluminium and the like optionally as an alloy or admixture with suitable agents.

An electrode as hereinbefore defined adapted for hole injection is suitably comprised of any suitable hole injecting material for example as known in the art, preferably comprises any suitable metal, alloy or semi-conductor such as indium tin oxide (ITO), tin oxide or other transparent conductor, PEDOT,

polyaniline or like polymer, gold and the like, optionally as an admixture with suitable agents.

A semiconducting layer as hereinbefore defined may comprise any organic (including organometallic) or inorganic semiconducting material. Preferably it comprises organic material such as small organic molecules, such as aluminium trisquinolate (Alq3), metal chelates and the like, polymers or mixtures thereof. In a preferred embodiment, the material comprises a polymer, preferably a conjugated polymer, for example PPV and derivatives such as poly(2-methoxy, 5-(2'-ethylhexyloxy) – *p*-phenylene vinylene) (MEH-PPV), or polyfluorene. Conjugated polymers combine good transport properties with strong luminescence and simple processing.

Other suitable semiconductor layers include compounds and alloys of gallium. Particularly preferred inorganic semiconducting materials are gallium arsenide and gallium nitride, and other like compound semiconducting materials which will suggest themselves to those skilled in the semiconducting art.

A device as hereinbefore defined may comprise any further supporting, sealing or protective layers and the like. Preferably a device as hereinbefore defined comprises a transparent rigid or flexible support layer such as quartz or glass or suitable synthetic equivalent such as polymeric substrates on which the device is constructed or onto which the constructed device is transferred, whereby the integrity and uniformity thereof is preserved. A first support layer may be used during the construction of the device, onto which either outer layer may be deposited as desired, and intermediate and opposing layers subsequently applied, and a second support layer to be used during use applied to either outer layer as desired. Any of these layers may be microstructured by any suitable means.

In a further aspect of the invention there is provided the novel use of a semiconducting organic layer with lateral microstructure in a device as hereinbefore defined.

In a further aspect of the invention there is provided the use of a device as hereinbefore defined as a light emitting display of any desired surface area and for portable or fixed purpose. A display may comprise a single continuous device or a mosaic of devices depending on the size and nature thereof.

Preferably a device is used for display purposes, such as electroluminescent TV or computer screens, back lighting of liquid crystal displays such as in watches and the like, very large area displays such as public information boards in airports and the like, small displays such as for household electrical goods including calculators, washing machines and the like, flexible displays, head-up (virtual reality) displays for training, entertainment purposes and the like, for example for aircraft pilot, road user training and the like; for improved efficiency applications such as for lighting of large areas, preferably by means of panelled low intensity (low brightness) wall or ceiling lighting in place of a plurality of independent lights, lighting powered by a battery source such as car brake lights, lighting in constant use such as traffic lights, warning and or road signs which may be optionally flashing or otherwise active, visible or near infra red security lighting.

Preferably a device as hereinbefore defined comprises or is adapted to be associated with means for mounting and operation thereof in known manner. Devices may be used in AC or DC operation, with the hereinbefore mentioned advantages of efficiency, brightness, control of polarisation and spectrum. The increased efficiency reduces power consumption, which is of particular benefit in battery-powered equipment.

In a further aspect of the invention there is provided a method for the production of a device as hereinbefore defined. The device may suitably be produced by any technique as known in the art with the additional step of producing a microstructure as hereinbefore defined. The method steps are those necessary to produce the device as hereinbefore defined.

Preferably a device as hereinbefore defined is produced by providing a first support layer of desired dimensions and laminating or coating this with successive layers. Preferably, metallic layers are deposited by thermal evaporation, electrolytic or reactive means.

Preferably an organic semiconducting layer as hereinbefore defined is coated in a layer for example by means of spin coating, dip-coating, printing, evaporation or epitaxial growth.

The microstructure as hereinbefore defined may be produced by any suitable method, such as embossing, photolithography, microcontact printing or laser holography. The microstructured layer(s) and/or electrode(s) may alternatively be deposited on a microstructured substrate or microstructured contact (e.g. ITO).

In one preferred embodiment features, for example corrugations, are created by exposing a photoresist or other further layer to at least one laser beam and subsequently depositing the semi-conducting layer and optionally further layers directly or indirectly onto the featured layer.

Preferably, the layer is exposed to an interference pattern created by a plurality of laser beams, preferably two laser beams.

Preferably, the layer is then cured where appropriate and is also preferably

coated (preferably by spin coating) with further layers.

In one preferred embodiment, the microstructure is then transferred from the photoresist layer to the substrate upon which it is supported, typically the transparent support to the LED structure.

In a further aspect of the invention there is provided a method for the operation of an LED as hereinbefore defined. Suitably an LED as hereinbefore defined is operated in known manner, by applying a voltage, causing a current to flow through the device. Advantageously a device as hereinbefore defined may be conveniently and reliably operated by virtue of the high efficiency thereof.

The invention is now illustrated in non-limiting manner with reference to the following figures and examples.

Preferred Embodiment

In the following, the manufacture, testing and key results of a solution processed single layer polymer LED with lateral microstructure is described. Firstly, the device structure is electrically stable, which is counter-intuitive due to the ratio of corrugation height to overall device thickness. It is found that the device efficiency is increased by a factor of 3 to 4, the emission spectrum is significantly altered with the vibronic structure (i.e. the peaks of the characteristic emission) appearing sharper. Also, the emitted light is polarised, which is an extremely significant observation.

(i) Fabrication of the grating

The corrugation of lateral pitch 400 nm was made by exposing the photoresist

to the interference pattern of two laser beams. The first step was to spin the photoresist (Shipley S1805) onto silica substrates to give films of thickness 500nm. The samples were then exposed to the interference pattern of two laser beams, generated using an Argon ion laser operating at 457.9 nm. Following exposure, the samples were developed, exposed to UV radiation (245 nm), and baked in air at up to 240 °C. The samples of corrugated photoresist were characterised by measurements of angle-dependent reflectivity and also by atomic force microscopy (AFM). These measurements confirmed the lateral period of 400 nm, but showed some sample to sample variation in grating depth. The peak to trough depth of grating determined by AFM was typically 80 nm.

(ii) Polymer LED structure

The device structure studied is a solution processed single layer polymer electroluminescent (EL) device containing the polymer MEH-PPV as the emissive layer. The structure is shown in Fig. 1.

A cross section showing the vertical layer structure of a device is shown in Fig. 2. Although all of the layers are shown with microstructure, this is dependent on the fabrication parameters and not necessary for functioning of the device.

As the photoresist is insulating, it is necessary to deposit a conducting anode on top of the photoresist. Gold has a work function comparable to ITO and has previously been used as a hole injecting contact (anode). A useful, i.e. relatively low absorption, gold layer should not be thicker than 20 nm and can be as thin as 8 nm. A layer of polyethylenedioxythiophene (PEDOT), which is a commercially available conductive polymer (Bayer AG, Germany), is deposited on top of the gold layer by spin-coating, and then baked for ten hours at 50 °C in vacuo. PEDOT is transparent in the visible and hence has no effect

on the emission spectrum. The emissive layer of MEH-PPV is then spin-coated onto the PEDOT layer. Under a vacuum of $5x10^{-6}$ mbar a thin calcium electrode is deposited which is capped by a thick aluminium electrode to prevent oxidation. Light is emitted through the silica substrate.

The completed device structure in this example is shown in Figures 3a and 3b. It has 8 pixels which may be addressed individually. The grating only covers one half of the substrate, so that the other half can be used as a direct comparison of both emission spectrum and efficiency.

(iii) Device characteristics

Fig. 4 shows the EL spectra measured of two adjacent pixel operating at the same bias and current. The peak (at 620 nm) is increased by a factor of ~3.5 and the total area of the spectrum is increased by a factor of ~5 for the corrugated LED with respect to the uncorrugated LED. The peaks on the corrugated LED are resolved much more clearly, whereas the uncorrugated emission appears broadened. This figure demonstrates that the grating gives rise to an increase in external device efficiency and the variation of the emission spectrum (improvement of colour purity).

In a separate experiment, the light output of two pixels on the corrugated and uncorrugated substrate was measured as a function of driving voltage. The results are shown in figure 5, and a substantial increase in the light output is obtained for the corrugated substrate. A standard analysis by taking into account the device current yields an external efficiency greater by a factor of ~2.5 for this example.

Fig. 6 shows the same graph on a logarithmic scale. It is clearly seen that both curves have a similar functional dependence on bias, indicating that a common electrical process gives rise to the electroluminescence (i.e. the injecting

properties of the anode are apparently not modified significantly by the inclusion of the grating). The emission characteristic of the corrugated substrate is however increase by a factor of ~2.5 with respect to the uncorrugated substrate. The ratio between the two curves is essentially constant between 4 and 10 V, which suggests the enhancement is indeed purely due to the effect of the grating on scattering out waveguide modes. The discontinuity in the characteristic of the uncorrugated substrate at 5 V is insignificant (due to the low level of light involved) and is most probably due to a minute electrical spark across the device.

Surface emitting LEDs generally emit unpolarised light. The results of an experiment to study the polarisation of the light emitted by a microstructured LED are shown in Fig. 7. The emitted light was detected through a polariser oriented either parallel or perpendicular to the direction of corrugation. A strong polarisation effect is observed for the corrugated LED. All three peaks in the electroluminescence spectrum display a polarisation dependence, the effect being strongest at the long wavelength peak. This is an extremely significant observation, as it demonstrates that polarised light emitted in the plane of the substrate is actually scattered out orthogonal to the substrate. It also demonstrates a means of fabricating a polarised EL device, which is of significant interest to LCD backlight applications.

(iv) General remarks

The corrugation is clearly visible at the top of the aluminium contacts through the entire device structure, which add up to a total thickness of ~400 nm. This demonstrates that the corrugation propagates throughout the LED and in particular through the polymer film, which gives rise to the efficiency enhancing scattering out of waveguide modes.

The main theoretical objection to the device structure presented in this example

here has previously been the ratio between the emissive layer thickness and the depth of the corrugation, which are clearly comparable. It was thought that an unevenness of 80 nm would lead to a highly non-uniform field across the emissive layer of comparable thickness, which generally leads to localised heating and electrical breakdown through shorting of the device. Pinhole formation and unevenness in ITO (spikes resulting from the relatively crude sputtering process) have been a major problem in organic LEDs. In the above example, all devices were free of shorts despite the strong modulation of the anode surface profile.

CLAIMS

1. A light emitting diode (LED), comprising an electrode adapted for electron injection, a second opposing electrode adapted for hole injection, one or more intermediate semi-conductor layers arranged therebetween and optionally one or more further layers wherein the LED comprises at least one microstructured feature adapted to manipulate emission or propagation of light.

2. A LED as claimed in Claim 1 wherein the microstructured feature is adapted to modify the intensity, polarisation or spectrum of emitted light.

3. A LED as claimed in Claim 1 or Claim 2 wherein the microstructured feature is generally lateral, such as to extend in a substantially parallel plane to the one or more semi-conductor layers and/or further layers of the device.

4. A LED as claimed in any preceding claim wherein the microstructured feature comprises a substantially periodic microstructure which is effective in controlling intensity, polarisation or spectrum of the emitted light.

5. A LED as claimed in Claim 4, wherein the substantially periodic microstructure is configured to Bragg scatter at least certain modes of emitted light.

6. A LED as claimed in Claim 4 or Claim 5 wherein the substantially periodic microstructure is specifically configured to increase efficiency

of emission by facilitating the emission, at least in part of light that would otherwise have been trapped in waveguide modes in the emissive layer.

7. A LED as claimed in one of Claims 4 to 6 wherein the substantially periodic microstructure is specifically configured to control the polarisation state of emitted radiation.

8. A LED as claimed in any one of Claims 4 to 7 wherein the substantially periodic microstructure is adapted to control or limit the frequency of radiation emitted in a given direction.

9. A LED as claimed in Claim 8 wherein the periodic microstructure consists of many regions of different periodicity to couple out light of different colours.

10. A LED in accordance with any one of Claims 4 to 9 wherein the substantially periodic microstructure is configured in conjunction with the photonic band-structure of the LED to allow for the preferential excitation of one or more desired wave guide modes.

11. A LED as claimed in any one of Claims 4 to 10 wherein the period is of microscopic scale in the order of 50 – 2000 nanometers, more preferably between 100 and 600 nm, more preferably between 350 and 450 nm and ideally 400nm.

12. A LED as claimed in any preceding claim wherein at least one semi-conducting layer, or a component thereof, is capable of light emission by luminescence.

13. A LED as claimed in any preceding claim wherein the microstructured feature is solid such that any or all microstructured layers are continuous.

14. A LED as claimed in any preceding claim wherein the microstructured feature provides the entirety of at least one of the microstructured layers and/or electrodes.

15. A LED as claimed in any preceding claim wherein the microstructured feature acts as a diffraction grating.

16. A LED as claimed in any preceding claim wherein the microstructured feature comprises features in the form of corrugation, which is in the form of one or more non-planar surfaces or layers and comprises an array of opposed projecting portions.

17. A LED as claimed in Claim 16 wherein the depth between peaks and troughs is of the order 5 to hundreds of nanometers.

18. A LED as claimed in Claim 17 wherein the depth is between 10 and 200 nm, more preferably between 20 and 120 nm.

19. A LED as claimed in any of Claims 16 to 18 wherein the corrugation is in the entirety of the layer.

20. A LED as claimed in any preceding claim wherein the microstructured feature comprises areas of modified refractive index.

21. A LED as claimed in Claim 20 wherein the portions of the layer with modified refractive index are present within the layer and are in the form of lines or areas of modified refractive index laterally across the layer.

22. A LED as claimed in any preceding claim comprising at least one organic or organometallic semi-conducting layer.

23. A LED as claimed in Claim 22 wherein the organic semi-conducting layer comprises a conjugated polymeric material.

24. A LED as claimed in any preceding claim comprising at least one inorganic semi-conducting layer.

25. The use of a semi-conducting organic or organometallic layer with lateral microstructure in a LED as claimed in any preceding claim.

26. The use of a LED as claimed in any of Claims 1 to 24 as a light emitting display of any desired surface area and for portable or fixed purpose.

27. A method for the production of a light emitting diode, wherein a laminar structure is fabricated comprising an electrode adapted for electron injection, a second opposing electrode adapted for hole injection, one or more intermediate semi-conductor layers placed therebetween, and optionally one or more further layers, and further comprising the step of adapting the LED such that there is at least one microstructured feature adapted to manipulate emission or propagation of light.

28. The method of Claim 26 wherein the adapting step comprises incorporating at least one semi-conducting organic layer with lateral periodic microstructure.

29. The method of Claim 27 wherein the semi-conducting organic layer is coated in a layer by means of spin coating, dip-coating, printing, evaporation or epitaxial growth.

30. The method of any of Claims 26 to 28 wherein the microstructured feature is produced by embossing, photolithography, microcontact printing or laser holography or by deposition on a microstructured substrate or microstructured contact.

31. The method of Claim 29 wherein microstructured features are created by exposing a photoresist or other further layer to at least one laser beam.

32. The method of Claim 30 wherein the microstructure is then transferred from the photoresist layer to the substrate upon which it is supported, typically the transparent support to the LED structure.

33. A LED adapted for light emission substantially as hereinbefore described with reference to the accompanying drawings.

34. A method for the production of a LED adapted for light emissions substantially as hereinbefore described with reference to the accompanying drawings.

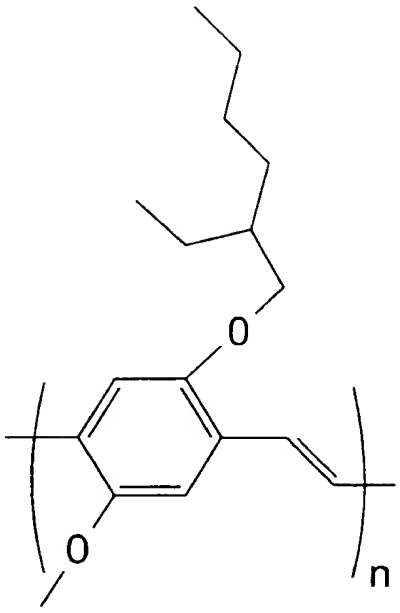

Fig. 1

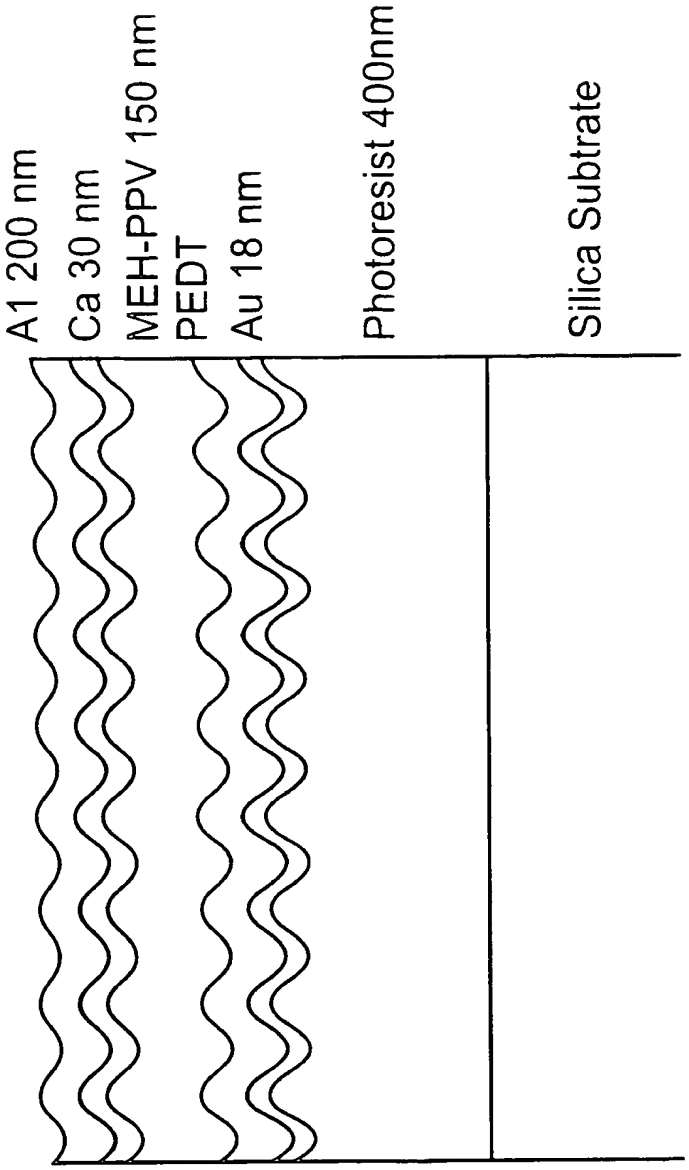
A1 200 nm
Ca 30 nm
MEH-PPV 150 nm
PEDT
Au 18 nm
Photoresist 400nm
Silica Subtrate

Fig. 2

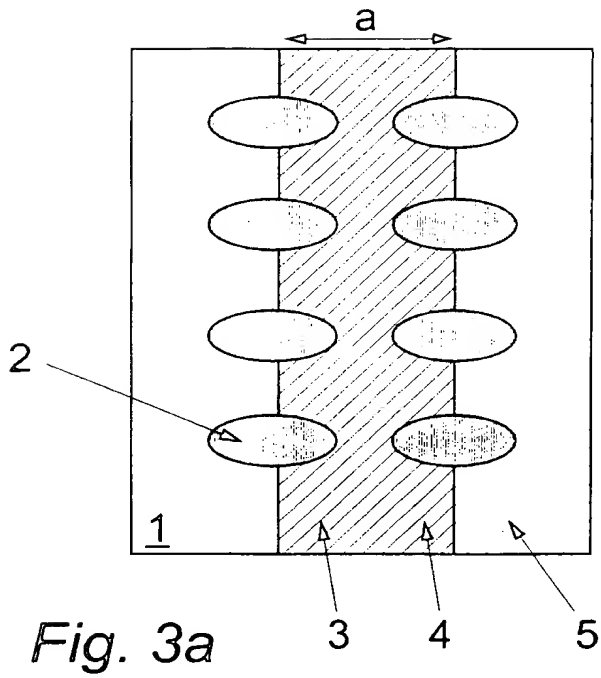

Fig. 3a

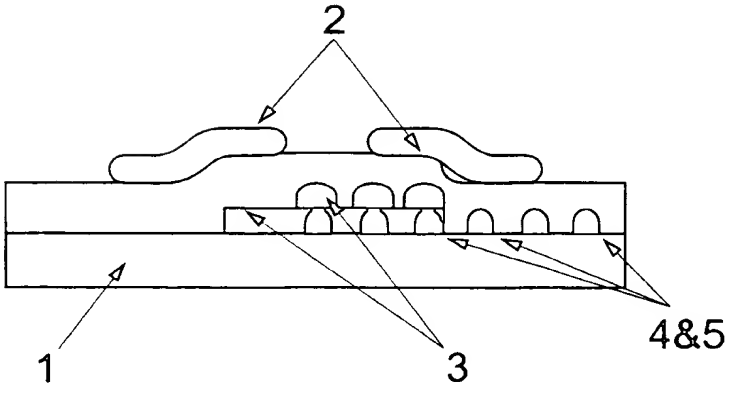

Fig. 3b

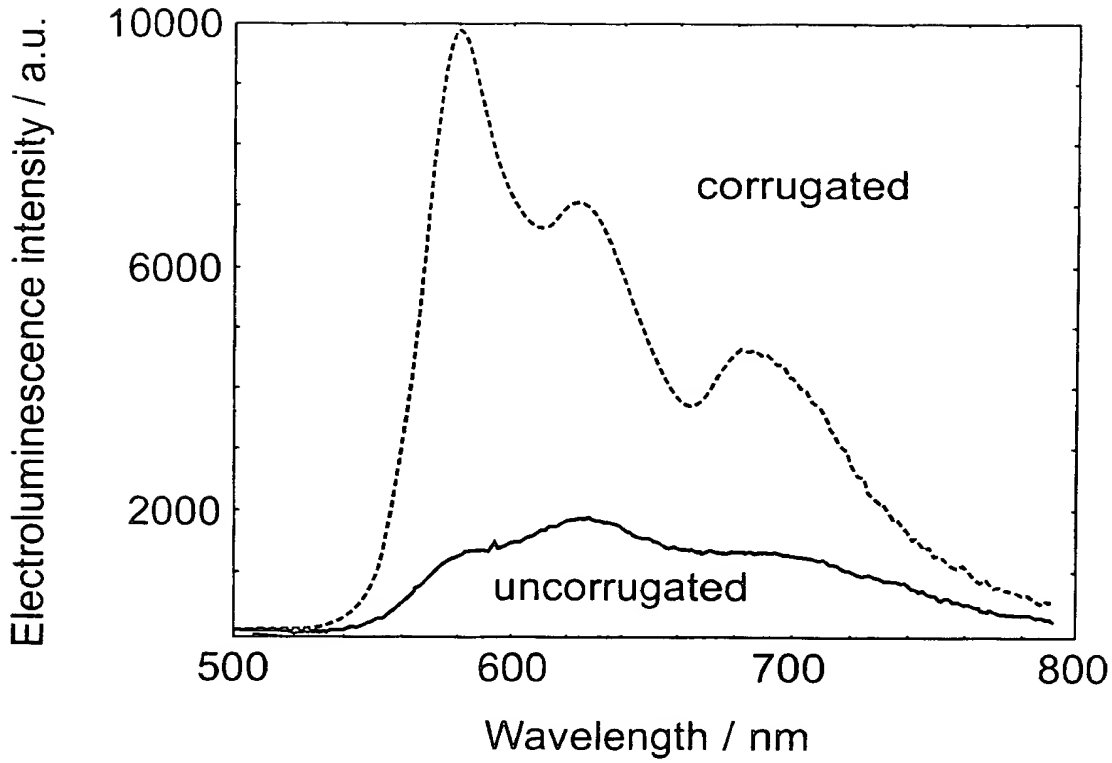
10000
6000
2000
Electroluminescence intensity / a.u.
corrugated
uncorrugated
500
600
700
800
Wavelength / nm

Fig. 4

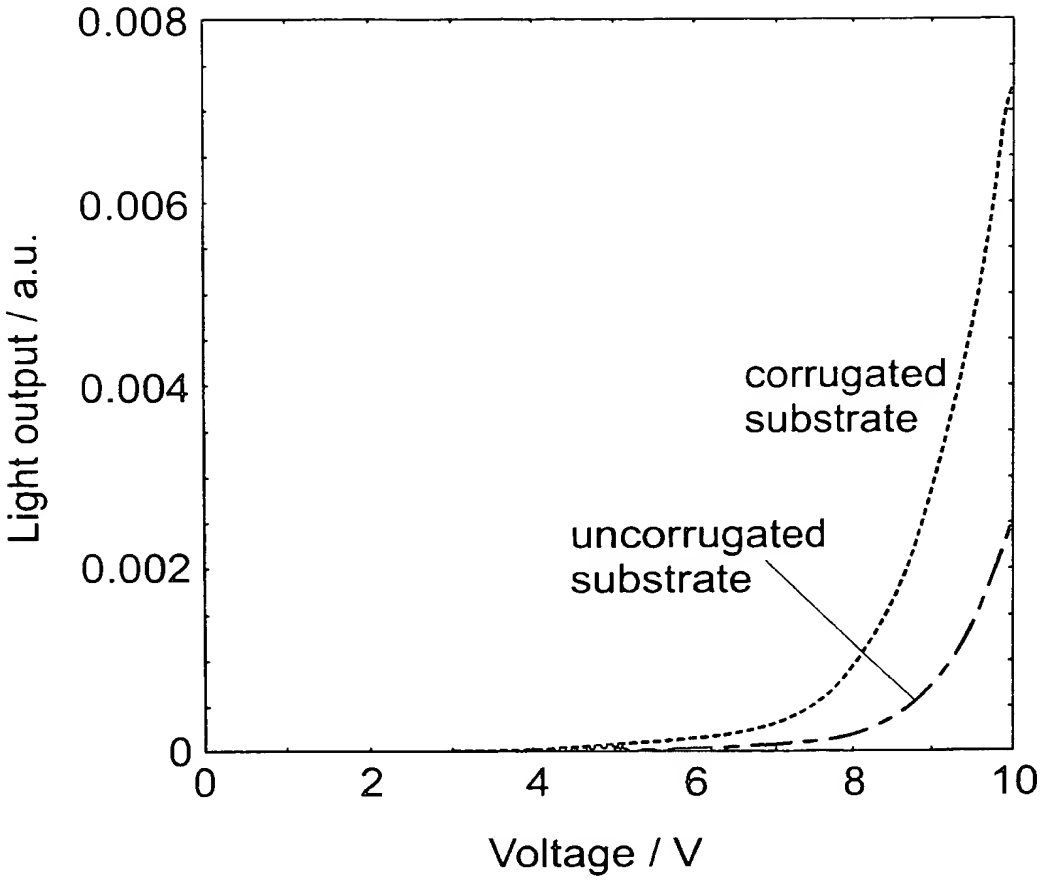
0.008
0.006
0.004
0.002
0
Light output / a.u.
corrugated substrate
uncorrugated substrate
0
2
4
6
8
10
Voltage / V

Fig. 5

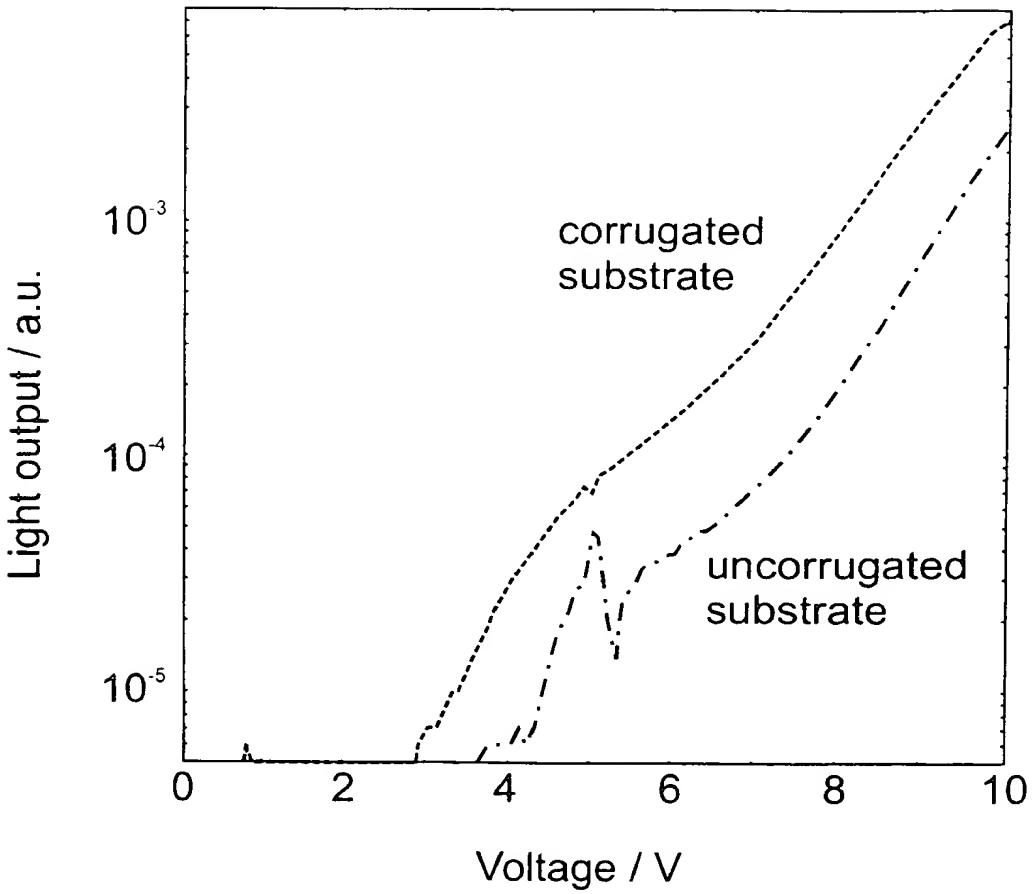
Light output / a.u.
10^{-3}
10^{-4}
10^{-5}
corrugated substrate
uncorrugated substrate
0
2
4
6
8
10
Voltage / V

Fig. 6

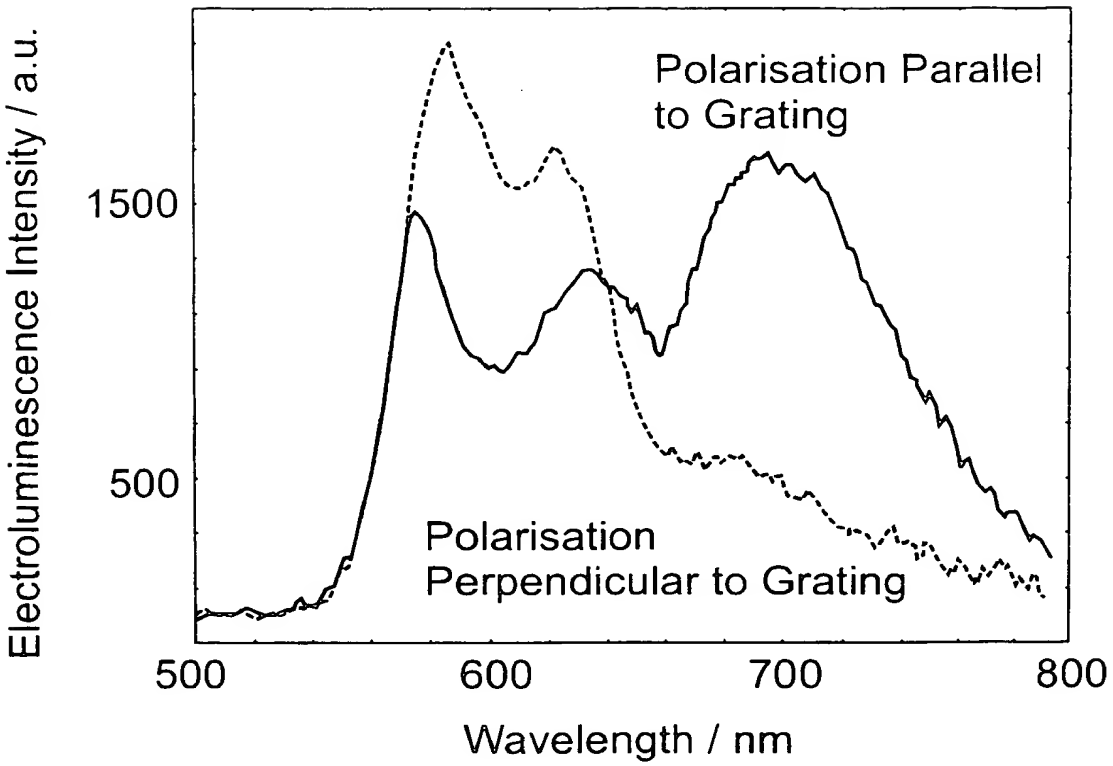
Electroluminescence Intensity / a.u.
1500
500
Polarisation Parallel
to Grating
Polarisation
Perpendicular to Grating
500
600
700
800
Wavelength / nm

Fig. 7

INTERNATIONAL SEARCH REPORT

Internat[illegible]pplication No
PCT/GB 00/01748

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20 H01L33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MATTERSON B J ET AL: "Effect of lateral microstructure on conjugated polymer luminescence" INTERNATIONAL CONFERENCE ON SCIENCE AND TECHNOLOGY OF SYNTHETIC METALS, MONTPELLIER, FRANCE, 12-18 JULY 1998, vol. 101, no. 1-3, pages 250-251, XP000931170 Synthetic Metals, May 1999, Elsevier, Switzerland ISSN: 0379-6779 the whole document --- -/--	1-8, 11-19, 22,23, 25-34

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2000	13/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01748

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 25313 A (BARNES WILLIAM LESLIE ;BRITISH TECH GROUP (GB); KITSON STEPHEN CHR) 11 June 1998 (1998-06-11) abstract	1-4,6, 10-16, 19,20, 27,31, 33,34
A	SHANHUI FAN ET AL: "High extraction efficiency of spontaneous emission from slabs of photonic crystals" PHYSICAL REVIEW LETTERS, 28 APRIL 1997, APS, USA, vol. 78, no. 17, pages 3294-3297, XP000931171 ISSN: 0031-9007 the whole document	1-4,6, 12,20, 21,24
A	WINDISCH R ET AL: "Light-emitting diodes with 31% external quantum efficiency by outcoupling of lateral waveguide modes" APPLIED PHYSICS LETTERS, 19 APRIL 1999, AIP, USA, vol. 74, no. 16, pages 2256-2258, XP002145910 ISSN: 0003-6951 cited in the application	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

rnat[illegible] pplication No
PCT/G[illegible]00/01748

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9825313 A	11-06-1998	EP 0946994 A	06-10-1999

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

14

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
FP2690 WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01748	12/05/2000	12/05/1999
International Patent Classification (IPC) or national classification and IPC H01L51/20		
Applicant UNIVERSITY OF DURHAM et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
11/12/2000	07.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Krause, J Telephone No. +49 89 2399 2829

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01748

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-20	as originally filed

Claims, No.:

1-32	as received on	07/05/2001	with letter of	04/05/2001

Drawings, sheets:

1/7-7/7	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	7, 9, 15, 16, 20, 21, 23, 26, 27, 29
	No:	Claims	1 - 6, 8, 10 - 14, 17 - 19, 22, 24, 25, 28, 30 - 32
Inventive step (IS)	Yes:	Claims	7
	No:	Claims	1 - 6, 8 - 32
Industrial applicability (IA)	Yes:	Claims	1 - 32
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Concerning Section V:

I. Claim 1:

1. The document WO-A-98/25313 (= D1) describes a light emitting diode (cf. page 8, lines 3 to 7, and Fig. 5), which comprises one or more intermediate semiconductor layers (55) and optionally one or more further layers, wherein the LED comprises at least one substantially periodic microstructured feature (53) adapted to manipulate emission and/or propagation of light by coupling non-radiative waveguide-modes to far-field radiation. Since the light emitting device in document D1 is fabricated from a sequence of layers on a substrate (51), it is implicitly clear that the LED must have two electrodes, one adapted for electron injection and one adapted for hole injection, sandwiching the layer structure. As a consequence, all the features of claim 1 are anticipated by document D1, and therefore claim 1 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. The document WO-A-98/25314 (= D2), has not been cited in the International Search Report. It describes (cf. page 7, line 21, to page 14, line 32, and Figs. 5 and 6) a light emitting diode having a microstructured feature adapted to manipulate emission or propagation of light as well. Also in document D2 electrodes are not explicitly described, but they belong to a light emitting diode and are therefore implicitly disclosed.

3. The arguments of the applicants put forward in their letter of 4 May 2001 are not convincing, because structural differences between the microstructured features of the device according to claim 1 and of the devices according to documents D1 or D2 have to be specified in the claim. At present, the microstructured feature of claim 1 should be the same as in D1 or D2.

II. Claims 2 to 22:

1. The additional features of dependent claims 2, 5, 6, and 8 are known from document D2. Therefore claims 2, 5, 6, and 8 do not appear to meet the requirements of Article

33(2) and (3) PCT.

2. As is described in document D2, only certain modes of the radiation field can oscillate in the light emitting diode. These modes differ from each other eg in the polarisation. Therefore the additional features of claim 3 are also known from document D2, and claim 3 is not considered to meet the requirements of Article 33(2) and (3) PCT.
3. The additional features of claims 4, 10, and 22 are known from either one of documents D1 and D2, and therefore claims 4, 10, and 22 are not considered to meet the requirements of Article 33(2) and (3) PCT.

4. The additional feature of claim 7 is not known nor rendered obvious from the available prior art. Claim 7 is therefore considered to meet the requirements of Article 33(2) and (3) PCT.

5. A person skilled in the art of semiconductor optical devices knows that the size of any feature designed to influence the emitted light depends on the wavelength of said light. He would thus obtain sizes as specified in claims 9, 15, and 16 by routine optimisation of parameters, taking into account his specific needs. Claims 9, 15, and 16 are thus not considered to meet the requirement of Article 33(3) PCT.

6. The additional features of claims 11 to 14 and 17 are known from document D1, and therefore claims 11 to 14 and 17 are not considered to meet the requirements of Article 33(2) and (3) PCT.

7. The additional features of claims 18 and 19 are known from document D2. Thus claims 18 and 19 do not appear to meet the requirements of Article 33(2) and (3) PCT.

8. The use of semiconducting organic materials in light emitting devices is generally known and would therefore also be contemplated in a device according to document D1 or document D2. Claims 20 and 21 are therefore not considered to meet the requirement of Article 33(3) PCT.

III. Claims 23 and 24:

1. As has been pointed out in the preceding paragraph II.8, semiconducting organic layers are generally known in the art. The provision of a lateral microstructure is described in document D2, and it is also evident to use such an organic layer in a light emitting diode. Thus the person skilled in the art would obtain all the features of claim 23 without employment of inventive skill, and therefore claim 23 does not appear to meet the requirement of Article 33(3) PCT.

2. The use of an LED in any light emitting display is self-evident for a person skilled in the art and has often been described. The person skilled in the art knows the subject-matter of claim 24 from his general knowledge, and therefore claim 24 is not considered to meet the requirements of Article 33(2) and (3) PCT.

IV. Claims 25 to 30:

1. The documents D1 and D2 describe also a method for the production of a light emitting diode, wherein a laminar structure is fabricated comprising one or more intermediate semiconductor layers and one ore more further layers, and further comprising the step of adapting the LED such that there is at least one substantially periodic microstructured feature adapted to manipulate emission or propagation of light by coupling non-radiative waveguide-modes to far-field radiation. The fabrication of two opposing electrodes is not mentioned but implicitly clear from document D1 or document D2. Thus all the features of claim 25 are known from either one of documents D1 and D2, and claim 25 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. The additional feature of dependent claim 26 is obvious from the fact that semiconducting organic layers are generally known and from documents D1 or D2. Therefore claim 26 is not considered to meet the requirement of Article 33(3) PCT.

3. The additional features of claim 27 are generally known to a person skilled in the art of organic semiconducting materials. Claim 27 is therefore also not considered to meet the requirement of Article 33(3) PCT.

4. The additional features of claims 28 and 30 are known from document D1 (cf. page 10, line 10, to page 12, line 13). Thus claims 28 and 30 are not considered to meet the requirements of Article 33(2) and (3) PCT.

5. The use of a laser beam as a light source is readily at the disposal of a skilled process engineer. Therefore claim 29 is not considered to meet the requirement of Article 33(3) PCT.

V. Claims 31 and 32:

1. A light emitting device as in claim 31 is known from document D1 or document D2. Therefore claim 31 is not considered to meet the requirements of Article 33(2) and (3) PCT.

2. A method as in claim 32 is known from document D1 or D2. Thus claim 32 is also not considered to meet the requirements of Article 33(2) and (3) PCT.

Concerning Section VII:

1. Claims 31 and 32 contain references to the description and the drawings. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here. Claims 31 and 32 should therefore be deleted.

2. Independent claims 1 and 25 are not in the two-part form in accordance with Rule 6.3(b) PCT, which in the present case would be appropriate, with those features known in combination from the prior art (document D1) being placed in the preamble (Rule 6.3(b)(i) PCT) and with the remaining features being included in the characterising part (Rule 6.3(b)(ii) PCT).

3. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art

disclosed in the documents D1 and D2 is not mentioned in the description, nor are these documents identified therein.

Concerning Section VIII:

1. Claims 2, 3, 5, 6, and 8 describe the features of the device in terms of a result to be achieved. Such a wording is not clear in the sense of Article 6 PCT, since the person skilled in the art reading the claims would need inventive thought to put the invention into practice.

2. The use of the word "substantially" in claims 1, 2, 4, and 25 obscures the scope of protection sought by these claims (Article 6 PCT).

3. Claim 23 refers to all preceding claims, but the semiconducting organic or organometallic layer is only defined in claims 20 and 21 (Article 6 PCT).

CLAIMS

1. A light emitting diode (LED), comprising an electrode adapted for electron injection, a second opposing electrode adapted for hole injection, one or more intermediate semi-conductor layers arranged therebetween and optionally one or more further layers wherein the LED comprises at least one substantially periodic microstructured feature adapted to manipulate emission and/or propagation of light by coupling non-radiative waveguide-modes to far-field radiation.

2. A LED as claimed in claim 1 wherein the substantially periodic microstructured feature is configured to increase efficiency of emission by facilitating the coupling, at least in part to useful far-field radiation so recovering some of the energy that would otherwise have been lost to non-radiative waveguide-modes.

3. A LED as claimed in Claim 1 or Claim 2 wherein the microstructured feature is adapted to modify the intensity, polarisation or spectrum of emitted light.

4. A LED as claimed in any preceding claim wherein the microstructured feature is generally lateral, such as to extend in a substantially parallel plane to the one or more semi-conductor layers and/or further layers of the device.

5. A LED as claimed in any preceding claim wherein the microstructured feature is specifically configured to control the polarisation state of emitted radiation.

6. A LED as claimed in any preceding claim wherein the microstructured feature is adapted to control the frequency of radiation emitted in a given direction.

7. A LED as claimed in Claim 6 wherein the periodic microstructure consists of many regions of different periodicity to couple out light of different colours.

8. A LED any preceding claim wherein the microstructured feature is configured in conjunction with the photonic band-structure of the LED to allow for the preferential excitation of one or more desired wave guide modes.

9. A LED any preceding claim wherein the microstructured feature is of microscopic scale in the order of 50 – 2000 nanometers, more preferably between 100 and 600 nm, more preferably between 350 and 450 nm and ideally 400nm.

10. A LED as claimed in any preceding claim wherein at least one semi-conducting layer, or a component thereof, is capable of light emission by luminescence.

11. A LED as claimed in any preceding claim wherein the microstructured feature is solid such that any or all microstructured layers are continuous.

12. A LED as claimed in any preceding claim wherein the microstructured feature provides the entirety of at least one of the microstructured layers and/or electrodes.

13. A LED as claimed in any preceding claim wherein the microstructured feature acts as a diffraction grating.

14. A LED as claimed in any preceding claim wherein the microstructured feature comprises features in the form of corrugation, which is in the form of one or more non-planar surfaces or layers and comprises an array of opposed projecting portions.

15. A LED as claimed in Claim 14 wherein the depth between peaks and troughs is of the order five to hundreds of nanometers.

16. A LED as claimed in Claim 15 wherein the depth is between 10 and 200 nm, more preferably between 20 and 120 nm.

17. A LED as claimed in any of Claims 14 to 16 wherein the corrugation is in the entirety of the layer.

18. A LED as claimed in any preceding claim wherein the microstructured feature comprises areas of modified refractive index.

19. A LED as claimed in Claim 18 wherein the portions of the layer with modified refractive index are present within the layer and are in the form of lines or areas of modified refractive index laterally across the layer.

20. A LED as claimed in any preceding claim comprising at least one organic or organometallic semi-conducting layer.

21. A LED as claimed in Claim 20 wherein the organic semi-conducting layer comprises a conjugated polymeric material.

22. A LED as claimed in any preceding claim comprising at least one inorganic semi-conducting layer.

23. The use of a semi-conducting organic or organometallic layer with lateral microstructure in a LED as claimed in any preceding claim.

24. The use of a LED as claimed in any of Claims 1 to 22 as a light emitting display of any desired surface area and for portable or fixed purpose.

25. A method for the production of a light emitting diode, wherein a laminar structure is fabricated comprising an electrode adapted for electron injection, a second opposing electrode adapted for hole injection, one or more intermediate semi-conductor layers placed therebetween, and optionally one or more further layers, and further comprising the step of adapting the LED such that there is at least one substantially periodic microstructured feature adapted to manipulate emission and/or propagation of light by coupling non-radiative waveguide-modes to far-field radiation.

26. The method of Claim 25 wherein the adapting step comprises incorporating at least one semi-conducting organic layer with lateral periodic microstructure of suitable period to facilitate the coupling, at least in part to useful far-field radiation so recovering some of the energy that would otherwise have been lost to non-radiative waveguide-modes.

27. The method of Claim 26 wherein the semi-conducting organic layer is coated in a layer by means of spin coating, dip-coating, printing, evaporation or epitaxial growth.

28. The method of any of Claims 25 to 27 wherein the microstructured feature is produced by embossing, photolithography, microcontact printing or laser holography or by deposition on a microstructured substrate or microstructured contact.

29. The method of Claim 28 wherein microstructured features are created by exposing a photoresist or other further layer to at least one laser beam.

30. The method of Claim 29 wherein the microstructure is then transferred from the photoresist layer to the substrate upon which it is supported, typically the transparent support to the LED structure.

31. A LED adapted for light emission substantially as hereinbefore described with reference to the accompanying drawings.

32. A method for the production of a LED adapted for light emissions substantially as hereinbefore described with reference to the accompanying drawings.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01748

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20 H01L33/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MATTERSON B J ET AL: "Effect of lateral microstructure on conjugated polymer luminescence" INTERNATIONAL CONFERENCE ON SCIENCE AND TECHNOLOGY OF SYNTHETIC METALS, MONTPELLIER, FRANCE, 12-18 JULY 1998, vol. 101, no. 1-3, pages 250-251, XP000931170 Synthetic Metals, May 1999, Elsevier, Switzerland ISSN: 0379-6779 the whole document --- -/--	1-8, 11-19, 22,23, 25-34

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2000	13/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/GB 00/01748

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 25313 A (BARNES WILLIAM LESLIE ;BRITISH TECH GROUP (GB); KITSON STEPHEN CHR) 11 June 1998 (1998-06-11) abstract	1-4,6, 10-16, 19,20, 27,31, 33,34
A	SHANHUI FAN ET AL: "High extraction efficiency of spontaneous emission from slabs of photonic crystals" PHYSICAL REVIEW LETTERS, 28 APRIL 1997, APS, USA, vol. 78, no. 17, pages 3294-3297, XP000931171 ISSN: 0031-9007 the whole document	1-4,6, 12,20, 21,24
A	WINDISCH R ET AL: "Light-emitting diodes with 31% external quantum efficiency by outcoupling of lateral waveguide modes" APPLIED PHYSICS LETTERS, 19 APRIL 1999, AIP, USA, vol. 74, no. 16, pages 2256-2258, XP002145910 ISSN: 0003-6951 cited in the application	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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